Drainage Water

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Chapter 4. Drainage Water

A. Introduction

This chapter focuses on the water that is collected from subsurface tile drainage systems, specifically the water quality, characteristics and water management alternatives. The quality of water is extremely important, because it determines if, how and where the water can be used. Constituents in drainage water may include salts, toxic trace elements and nutrients. The quality of water can limit its potential uses, as well as increase the cost of treatment and the operation and maintenance of treatment equipment and facilities. Water quality and utility declines as salinity (measured as electrical conductivity (EC) or as total dissolved solids (TDS)) increases.

B. Agricultural Drainage Water Characteristics:

1) Tailwater and Tilewater

There are two types of drainage water that result from irrigated agriculture. These are tailwater and tilewater.

- Tailwater (surface drainage water) is water that was applied to irrigate crops, but does not infiltrate the soil and is collected as runoff.
- Tilewater (subsurface drainage water) is water that was applied to irrigate crops, infiltrates through the soil profile, and is collected by the subsurface drains. This water is pumped from the drains to the surface and then emptied into a surface drainage ditch or collector pipe.

When not specified, drainage water usually refers to subsurface drainage.

Subsurface drainage water is usually of lower quality than the original irrigation water because it has traveled through the soil column and picked up various compounds and substances such as salts, soil particles, inorganic trace elements and organic compounds. As a result, subsurface drainage water from different locations will have different compositions. For example, in most regions of the west side of the San Joaquin Valley sodium sulfate is more predominant than sodium chloride, but there are areas where the chloride form is more abundant (SJV Drainage Program Report, 1990). Trace element levels also can differ markedly. At Red Rock Ranch (near Five Points), the drainage water is very high in selenium, whereas at Westlake Farms (near Stratford), selenium is lower, but molybdenum is very high.

2) Salts

Salts are usually found in irrigation and drainage water, but the composition and concentration varies. Salts commonly found in subsurface drainage water include sulfates, chlorides, carbonates, and bicarbonates of the elements sodium, calcium and magnesium. The salts originate from chemical weathering of minerals found in the soil's parent material, which in the case of the Valley's west side, is marine in origin (alluvial fan from the coastal range), and is therefore high in salts. To a lesser extent, irrigation water and groundwater also add salt to soil. The primary source of the imported irrigation water for the west side is surface water from the Sacramento-San Joaquin Delta. Although very low in salt, the volume of water imported results in an average of 800,000 tons of salt being imported to the northern San Joaquin Valley each year. Approximately 335,000 tons of salt leave by way of the San Joaquin River and the rest remains primarily in the soil. Similarly, about 2 million tons of salt are imported into the southern San Joaquin Valley by way of its irrigation water delivery system and the Valley's geology. Because the Valley is a hydrologically closed basin, most of the salt remains (DWR, 2001). Additional sources of salt to west side soils include local precipitation and runoff, pesticides, fertilizers and soil amendments such as manure, gypsum and lime.

3) Water Salinity

Common ways of expressing water salinity are **EC** (electrical conductivity) expressed in decisiemens per meter (dS/m) or **TDS** (total dissolved solids) expressed in parts per million (**ppm**) or milligram per liter (**mg/L**), which is equivalent to ppm.

EC may sometimes be expressed using older units of millimhos per centimeter (mmhos/cm) or micromhos per centimeter (µmhos/cm), which are equivalent to dS/m and 1,000 times dS/m, respectively. And for water salinity, an alternative unit for TDS is milliequivalents per liter (**meq/L**) rather than ppm or mg/L.

Conversion factors for EC ⇨ TDS increase as the salinity increases. (See table below.) The conversion factors recommended for the west side San Joaquin Valley are different than those given in Ayers & Wescot (1985), the most commonly used water quality guide. The difference is attributed to the larger sodium sulfate component, as compared to sodium chloride, in west side drainage waters. Among drainage waters, variation in conversion factors between EC and TDS has been found, reaching as high as 1,200 to 1,400 for highly saline drainage waters having an exceptionally high sodium sulfate composition (i.e. a 30 dS/m sample could have a TDS of 36,000 to 42,000 ppm. However, for the most part, the conversions shown will apply.

Table 4-1. EC ⇨ TDS Conversion Table

TDS (ppm) = 740 x EC (dS/m); when EC is less than 5 dS/m
TDS (ppm) = 840 x EC (dS/m); when EC is between 5 and 10 dS/m
TDS (ppm) = 920 x EC (dS/m); when EC is greater than 10 dS/m

TDS (meq/l) = 10 x EC (dS/m)

The table below gives general recommendations for the use of irrigation waters based on salinity. More detailed information is given in Table 5-1 in Chapter 5.

Table 4-2. Salinity-Irrigation Water Table

Below 0.5 dS/m	Salinity is not a problem for the crop. Depending on soil texture, water penetration problems could occur due to low salt content.
0.5 to 1.5 dS/m	No hazard-to-low salinity hazard.
1.5 to 3.0 dS/m	Low-to-medium salinity hazard. May be used for salt-sensitive crops, but at the high end of this range may not be advisable and/or yield reduction is likely.
Above 3.0 dS/m	Salinity hazard. Most suitable for salt-tolerant crops. Leaching is essential.

Highly saline water may be used for irrigation, given proper crop selection and soil and water management. However, these guidelines provide a starting point for evaluating whether a water source does or does not pose a salinity hazard. There are examples where irrigation water with salinity greater than 3 dS/m has been successfully used for irrigation even with crops that are not classified as "salt-tolerant".

4) Water Sodicity (sodium in the water)

Sodicity refers to the amount of sodium in the water. This can be expressed as the exchangeable sodium percentage (**ESP**). More commonly, the sodium is expressed in relation to the calcium and magnesium levels in the water. This is called the sodium adsorption ratio or **SAR**. The equation is:

$$SAR^{*} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

**when Na, Ca, and Mg are given in meq/L*

Irrigation water with a sodium adsorption ratio (SAR) $\geq$ 10 or an exchangeable sodium percentage (ESP) 13 is likely to infiltrate poorly when applied to a medium-or-fine-textured soil, particularly if the salinity of the water is low. However, the infiltrability of water is really a function of both SAR and EC. A high SAR water with very low salinity (< 0.5 dS/m EC) will infiltrate much slower than a water of the same SAR and higher salinity.

A complete table listing combinations of sodium adsorption ratio (SAR) and salinity (ECw) and the degree of restriction on use of the water is given in Ayers and Westcot (1985) and is discussed in a handy manual entitled "Agricultural Salinity and Drainage Manual" (Hanson, Grattan, and Fulton, 1999).

5) Toxic Trace Elements

Because the soils on the west side originated from marine sediments, they contain salts and potentially toxic trace elements (selenium, molybdenum, arsenic, uranium, and boron) that dissolve in irrigation water and leach into groundwater. Most of the elements originate naturally from the soils, but imported irrigation water also may contain some trace elements. Among those listed below, boron is the trace element of greatest concern for crop production. Where salinity is a problem on the west side, boron toxicity is often a problem as well. These trace elements are classified as "substances of concern" because of their potential to negatively impact water quality, public health, agricultural productivity and/or fish and wildlife (SJV Drainage Program Report, 1990).

- **Selenium** is found in varying concentrations in much of the soil and water on the west side San Joaquin Valley. It is the element of greatest concern. At high concentrations, selenium is toxic to wildlife and it was traced to the waterfowl poisonings that led to closure of the San Luis Drain.
- **Molybdenum** is an essential trace element for plants and some animals, but it can be toxic to ruminant animals. The CVRWQCB recommendation for molybdenum in water for agricultural usage is 10 ppb (SJV Drainage Program Report, 1990).
- **Boron** is found in varying concentrations in much of the soil and water on the west side of the San Joaquin Valley. Many agronomic crops are sensitive to boron. Although it has been found to reduce the growth rate of chicks, wildlife risks are lower than for the other trace elements listed.
- **Arsenic** is a mammalian toxin.
- **Uranium** is radioactive element found in specific locations throughout the valley.

6) Nutrients

Nutrients, such as nitrogen in organic and inorganic forms (ammonium and nitrate) and phosphate in organic and inorganic forms, may be found in drainage waters. Careful water and fertilizer management are needed to minimize nutrient losses from soil, which potentially results in reduced growth and yields and compromises water quality. However, the leached nutrients could be considered an asset if the subsurface drainage water containing these nutrients is collected and applied to other crops, as in an IFDM system.

C. Utilizing Drainage Water for Irrigation

Several management schemes exist for use of saline water source in an irrigation program. These schemes differ regarding where, when, and how the saline water is applied to the grower's field, and whether non-saline water is included in the cropping system. Alternative scenarios are given in the following sections. It will be part of the designer's job to select the appropriate scheme for the proposed system.

1) Sequential Use

In this scheme, part of the farm, or sub-region, is designated as the reuse area. It consists of a sequence of fields within the boundaries of a farm, or an irrigation district, that are irrigated with saline water (see Grattan and Rhoades, 1990). That is, the drainage collected under one field – which is more saline than the irrigation water – is then used to irrigate the next field in the sequence and so on. The main purpose is to obtain an additional economic benefit from the available water resources, minimize the area affected by shallow water tables, and reduce the volume of drainage water that requires disposal. IFDM is one type of sequential reuse.

Two other methods have been field-tested for utilizing saline water. Both require an ample supply of good quality water and saline water to be available for irrigation throughout the season.

2) Blending

Blending involves mixing saline water and high quality water together to achieve an irrigation water of suitable quality based on the salt tolerance of the chosen crop. The blended water is then used for irrigation. The AndrewsAg IFDM system blends fresh water and drainage water for their salt-tolerant cotton. Blending is not attractive if saline water does not supply at least 25 percent of the total irrigation water requirement for the crop. That is, the costs and risks of the increased management associated with adding salts to the irrigation supply will likely outweigh the benefits from increasing the total water supply by only a slight-to-modest amount.

3) Cyclic Use

The "cyclic" method was first introduced and tested by Rhoades (1984). Saline drainage water is used solely for certain crops and only during certain portions of their growing season. The objective of the cyclic strategy is to minimize soil salinity (i.e. salt stress) during salt-sensitive growth stages, or when salt-sensitive crops are grown.

With a cyclic strategy, the soil salinity profile is purposefully reduced by irrigation with good quality water, thereby facilitating germination and permitting crops with lesser tolerances to be included in the rotation. The cyclic strategy keeps the average soil salinity lower than that under the blending method, especially in the upper portion of the profile, which is critical for emergence and plant establishment (Grattan and Rhoades, 1990).

4) Combining Strategies

These strategies are not mutually exclusive. In fact, a combination may be most practical in some cases. For example within a sequential reuse scheme, blending and/or cyclic methods may be used on occasion to germinate and establish the salt-tolerant crops. This is particularly true for the establishment of salt-tolerant perennial forages, some of which may require at least a full year of freshwater irrigation prior to applying the saline drainage water. Also, the blending and cyclic strategies are primarily suitable for drainage water that is relatively low in salinity (< 8 dS/m= 6700 ppm TDS). Another example is in the AndrewsAg IFDM which is a sequential re-use but for the cotton, fresh water and drainage water has been blended, for example in a ratio of two-thirds freshwater and one-third drainage water when drainage flows were low.

5) Single Use

A few examples exist, e.g. the San Joaquin River Water Quality Improvement Project (SJRIP) operated by Panoche Drainage District, where drainage water is used only a single time for the irrigation of salt-tolerant crops and forages. In this case, at the onset of the project, only a small portion of the 4,000-acre re-use area had subsurface drainage and the main objective was to displace some of the drainage water being discharged to the San Joaquin River under on a special agreement (Grasslands Bypass Project) in order to meet water quality objectives. Although not the preferred system for long-term sustainability, single use may be employed in the initial stages of a drainage water re-use project when a means of drainage water disposal is needed and a long-term commitment and funds for the installation of a complete drainage system have not been secured. However, in order to control soil salinization, maintain the permeability of the soil and productivity of the plants growing in the re-use area, and stay in compliance with environmental regulations, it is likely that tile drains would need to be installed throughout the re-use area. Eventually, it would need to convert to a multiple re-use system similar to IFDM.